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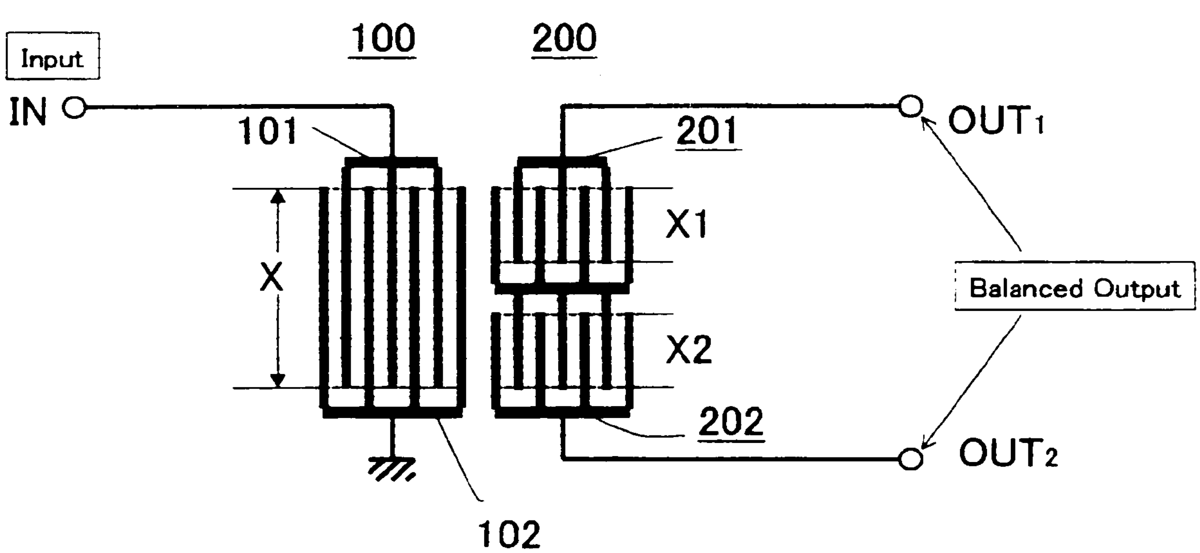
(54) **Surface acoustic wave device**

(57) A surface acoustic wave device (10) includes an input interdigital transducer (100) and an output interdigital transducer (200), disposed on a surface acoustic wave propagation path of a piezoelectric substrate. One (200) of the interdigital transducers has two divided interdigital transducers (201, 202) made of electrode fingers (101, 102) having half the aperture length of electrode fingers in the other interdigital transducer (100). The two divided interdigital transducers (201, 202) are serially-coupled and mutually-offset by half a SAW wavelength, such that terminals led from them carry signals 180° out of phase.

FIG. 3



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Description

[0001] The present invention relates to a surface acoustic wave device, and in particular to a surface acoustic wave device in which any one of an input and output has a balanced or differential terminal pair.

[0002] The surface acoustic wave device is widely used as a filter in a high frequency circuit of a radio apparatus represented by a portable telephone or the like. In recent years, in such high frequency circuits, an integrated circuit element (IC) having a balanced or differential input and output has been used.

[0003] On the contrary, a filter using a conventional surface acoustic wave device (hereinafter appropriately referred to as a surface acoustic wave filter) has unbalanced I/O terminals. For this reason, for example, as shown in Fig. 1, in a case of connecting with a mixer circuit IC 3, an unbalanced-balanced transforming part which is called a balun, or a transformation circuit 2 constituted by separate parts is necessary between a surface acoustic wave filter 1 and the mixer circuit IC 3.

[0004] Furthermore, the surface acoustic wave filter normally has an I/O impedance of 50Ω, and on the other hand, in many cases, an impedance of the mixer circuit IC 3, etc. having a balanced terminal pair is as high as about 100 to 200Ω. An impedance transformation circuit is required for connecting such an IC with the surface acoustic wave filter.

[0005] However, this leads to an increase in the number of circuit parts being used in the radio apparatus. Furthermore, there is a demand for further downsizing and space-saving in circuit design.

[0006] It is a consideration of the present invention to provide a small-sized surface acoustic wave device having an unbalanced-balanced transformation function and a function of impedance transformation.

[0007] According to a first aspect of the present invention there is provided a surface acoustic wave device, comprising an input interdigital transducer and an output interdigital transducer, disposed on a surface acoustic wave propagation path of a piezoelectric substrate, wherein when an aperture length of an electrode finger of the input or output interdigital transducer is denoted by X, the output or input interdigital transducer has two divided interdigital transducers having an electrode finger in which each aperture length is denoted by substantially X/2, and wherein the two divided interdigital transducers are serially-connected (coupled), and the electrodes of the respective electrode fingers are led from the two divided interdigital transducers, and are disposed so that two output and input signals connected to a balanced terminal pair have phases different by 180°.

[0008] According to a second aspect of the present invention there is provided a surface acoustic wave device, comprising a plurality of interdigital transducers disposed on a surface acoustic wave propagation path of a piezoelectric substrate, and a reflection electrode disposed at both sides, wherein the plurality of interdigital transducers contain a first type of interdigital transducer and a second type of interdigital transducer disposed alternately, wherein when an aperture length of an electrode finger of the first type of interdigital transducer is denoted by X, each of the second type of interdigital transducers has two divided interdigital transducers having an electrode finger in which each aperture length is denoted by substantially X/2, and wherein the first type of interdigital transducer is connected to an unbalanced input or output terminal pair, and the two divided interdigital transducers are serially-connected, and the electrodes of the respective electrode fingers are led from the two divided interdigital transducers, and are connected to a balanced terminal pair, and the respective electrode fingers of the two divided interdigital transducers are disposed so that the phases of signals in the balanced terminal pairs differ by 180°.

[0009] Preferably in the first or second aspect of the present invention, a position of the electrode finger at a side connecting with the balanced terminal is mutually offset (slid) by 1/2 an acoustic wave length, in the two divided interdigital transducers.

[0010] Preferably in the second aspect of the present invention, the plurality of interdigital transducers constitutes a double mode filter using three interdigital transducers.

[0011] Preferably in the second aspect of the present invention, there are five or more interdigital transducers, constituting a multi-electrode filter.

[0012] According to a third and fourth aspect of the present invention there is provided a surface acoustic wave device comprising two or more filters being cascade-connected, of which an outermost filter is constituted by the surface acoustic wave device according to the above first or second aspect respectively, and a balanced terminal pair for an input or output.

[0013] Another aspect of the invention is as defined by independent claim 10.

[0014] The piezoelectric substrate may be a 40° to 44° rotated Y-X $LiTaO_3$ substrate in any of the above aspects of the present invention.

[0015] Alternatively, the piezoelectric substrate may be a 66° to 74° rotated Y-X $LiNbO_3$ substrate in any of the above aspects of the present invention.

[0016] A detailed description of embodiments of the present invention will now be given, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a view for explaining a case where a conventional surface acoustic wave device is connected to an IC circuit having a balanced input;

Fig. 2 is a view for explaining a case where a surface acoustic wave device according to the present invention is connected to the IC circuit having the balanced input;

Fig. 3 is a view showing the surface acoustic wave device according to a first embodiment of the

present invention:

Fig. 4 is a view for explaining operation according to the embodiment of Fig 3:

Fig. 5 is a view showing the surface acoustic wave device according to a second embodiment of the present invention:

Fig. 6 is a view showing the surface acoustic wave device according to a third embodiment of the present invention:

Fig. 7 is a view showing the surface acoustic wave device according to a fourth embodiment of the present invention:

Fig. 8 is a view showing the surface acoustic wave device according to a fifth embodiment of the present invention:

Fig. 9 is a view showing the surface acoustic wave device according to a sixth embodiment of the present invention:

Fig. 10 is a view showing the surface acoustic wave device according to a seventh embodiment of the present invention:

Fig. 11 is a view showing the surface acoustic wave device according to an eighth embodiment of the present invention: and

Fig. 12 is a view showing the surface acoustic wave device according to a ninth embodiment of the present invention.

[0017] The description of the embodiments below is made for understanding of the present invention: however. the scope of the present invention is not limited to the embodiments. the drawings. and the description thereof.

[0018] Fig. 2 is a view showing an adaptive example of a surface acoustic wave device 10 according to the present invention as a surface acoustic wave filter. which leads to a mixer circuit IC 3 similarly to that in Fig. 1.

[0019] The surface acoustic wave filter embodying the present invention has an unbalanced-balanced transformation function and an impedance transformation function. Thus. it is possible to set (connect) a balanced input of the mixer circuit IC 3 to an (appropriate) input impedance. Accordingly. there is no need to use the independent unbalanced-balanced transformation function and impedance transformation function circuit. which are necessary in Fig. 1. Thus. it is possible to realize a downsizing of the device.

[0020] Fig. 3 shows an electrode structure of the surface acoustic wave device 10 according to a first embodiment of the present invention. for use in the example in Fig. 2.

[0021] In Fig. 3. a single input interdigital transducer (IDT) 100 and output interdigital transducer (IDT) 200 are disposed on a propagation path of surface acoustic waves formed on a piezoelectric substrate to be described later in detail.

[0022] A first interdigital electrode finger (set of fingers) 101 at one side of the input IDT 100 is connected to an input signal terminal IN. and a counter second interdigital electrode finger 102 is grounded. A width X in which the first electrode finger 101 and second electrode finger 102 overlap is an aperture length of the input IDT 100.

[0023] On the other hand. the output IDT 200 has first and second interdigital or crossover interdigital transducers (IDT) 201. 202 having aperture lengths X_1 X_2 substantially half the aperture length X within a range of the aperture length X of the input IDT 100.

[0024] One electrode finger of the first crossover IDT 201 and one electrode finger of the second crossover IDT 202 are connected to balanced output terminal pairs OUT1. OUT2. respectively. and further the other electrode fingers of the first and second crossover IDTs 201. 202 are provided in common (configured so as to be commonly connected. respectively).

[0025] Here. in particular. the electrode fingers of the first and second IDTs 201. 202 are configured so that the positions of the electrode fingers are spaced apart by half a cycle (mutually slid by 1 cycle. namely by 1/2 of a surface acoustic wavelength).

[0026] Fig. 4 is a view for explaining an operational principle in an electrode structure of Fig. 3. and in particular. showing typical behaviour when the surface acoustic waves (hereinafter SAW) propagate between an input and output. Here. an upside (upper side) of the two divided output IDTs 201. 202 is called a track 1. and a downside (lower side) thereof is called a track 2.

[0027] A certain moment when the surface acoustic wave device is operating will now be considered. First. an input electric signal is transformed into a SAW by the input IDT 100. This SAW is propagated on the piezoelectric substrate. Furthermore, the SAW is incident on each of the first and second crossover IDTs 201. 202 of the output IDT 200 as the track 1 and track 2. In Fig. 4, each SAW amplitude of the tracks 1, 2 is shown.

[0028] When the SAW is incident on the tracks 1, 2. the SAW is transformed again into an electric signal. At this time. the position of the electrode finger is slid at half wavelength between the tracks 1 and 2. For this reason. phases of the electric signal obtained by output terminal pairs OUT1. OUT2 are mutually slid at 180°. to which acceptable ±10°~15° deviations may occur.

[0029] In other words. the output terminals OUT1 and OUT2 yield electrical signals having a phase difference of 180° because they are connected to respective electrode fingers 201 and 202 which are mutually offset by half a SAW amplitude cycle in the direction of Track 1 and Track 2.

[0030] That is. in the embodiment of Fig. 3. it is apprehensible that a balanced terminal pair is formed between the output terminal pairs OUT1 and OUT2. thereby realizing an unbalanced input-balanced output. Next. an I/O impedance will be considered. A capacitance impedance is formed between the electrode fingers of the IDT. and a magnitude of the capacitance impedance is

determined according to an interval of the electrode fingers and aperture length.

[0031] In Fig. 4, an interval A-B between the electrode fingers of input IDT 100 is equal to an interval C-D of the electrode fingers of the output IDT 200. Accordingly, when the input impedance is 50Ω, since in the impedance of the IDT 201 at a track 1 side an aperture length X1 of the IDT 201 is about half the aperture length X of the input IDT 100, the impedance becomes doubled, or about 100Ω.

[0032] On the other hand, the impedance of the IDT 202 at the track 2 side similarly becomes about 100Ω. Accordingly, when viewed between the balanced terminal pairs OUT1 and OUT2, since the two output IDTs 201, 202 are serial-connected, the entire impedance at the output side becomes about 200Ω. Thus, it becomes possible to transform the I/O impedance from 50Ω to 200Ω.

[0033] Fig. 5 is a view showing a second embodiment of the present invention. Fig. 5 shows an electrode finger configuration of the IDT formed on the piezoelectric substrate similarly with Fig. 3. The two input IDTs 101, 102 and the one output IDT 200 interposed between the input IDTs, are disposed between reflectors 301, 302 on either side, forming a so-called double mode filter configuration.

[0034] Here according to the present invention, when the output IDT 200 is divided into upper and lower IDTs 201, 202 in the same manner as in the example of Fig. 3, the two signals output therefrom form balanced outputs at the output terminal pair OUT1 and OUT2.

[0035] In a case where such a double mode filter is used, it is possible to realize an unbalanced-balanced filter of high attenuation.

[0036] Furthermore, in the embodiment of Fig. 5 also, the impedance transformation function is the same as that described previously in Fig. 4.

[0037] Fig. 6 shows a third embodiment of the present invention, and shows the electrode finger configuration of an IDT formed on the piezoelectric substrate in the same manner as in the preceding example. This embodiment also has a double mode filter configuration. It is characterized in that two combinations (IDTs 201, 202, and IDTs 203, 204) of the IDTs are used at an output side unlike in the embodiment of Fig. 5.

[0038] The same characteristic as in the second embodiment can be obtained, and it is applied in a case where the output impedance is desired to be set lower than the second embodiment. That is, as described above, the two combinations (IDTs 201, 202, and IDTs 203, 204) of the IDTs are used, and these are parallel-connected to the balanced output terminal pairs OUT1, OUT2.

[0039] Accordingly, when the I/O impedance of the input IDT 100 is 50Ω, in the embodiment of Fig. 6, the output impedance becomes 100Ω.

[0040] Fig. 7 shows a fourth embodiment of the present invention, and has a multi-electrode type surface acoustic wave filter comprising 5 IDTs of which three input IDTs 101 to 103 and two sets of the output IDTs 201 to 202, and 203 to 204 are alternately disposed.

[0041] In general, the multi-electrode type can be defined as containing a plurality of (three or more) IDTs. The embodiment of the double mode type of Fig. 6 corresponds to a case of containing a minimum amount of IDTs in the multi-electrode type.

[0042] Here, in this configuration, each output of the two sets of the output IDTs 201 to 202, and 203 to 204 is led to the balanced output terminal pairs OUT1, OUT2. In the configuration of this embodiment, it is possible to realize a balanced filter of a relatively wide passband width.

[0043] Fig. 8 shows a fifth embodiment of the present invention, and shows a configuration of the electrode finger of the IDT formed on the piezoelectric substrate in the same manner as in the preceding examples.

[0044] The fifth embodiment is same as in the embodiment of Fig. 7 in that the multi-electrode configuration is used, but the three sets of the IDTs 201 to 202, 203 to 204, and 205 to 206 are used at the output side. The same characteristic as in Fig. 7 can be obtained, and this embodiment is applied in a case where the output impedance is desired to be set lower than the embodiment of Fig. 7.

[0045] Fig. 9 shows a sixth embodiment of the present invention, and shows a configuration of the electrode finger of the IDT formed on the piezoelectric substrate in the same manner as in the preceding example. The multi-electrode type filter is configured by a two-stage cascade-connection. That is, first stage IDTs 103 to 105 are cascade-connected to second stage IDTs 113 to 115.

[0046] Furthermore, as the output IDT of the filter at the second stage, the two sets of IDTs 201 to 202, and 203 to 204 are used. The output of the two sets of IDTs 201 to 202, and 203 to 204 is led out to the balanced output terminal pairs OUT1, OUT2.

[0047] When such a configuration is used, since the cascade connection is made at the first stage and second stage, it is advantageous that an attenuation amount can be largely taken.

[0048] Fig. 10 shows a seventh embodiment of the present invention, and shows a configuration of the electrode finger of the IDT formed on the piezoelectric substrate in the same manner as in the preceding example. The seventh embodiment has the same configuration as in the embodiment of Fig. 5 in that serial-resonators configured so as to have an IDT 110 and reflecting IDTs 111, 112 at an input side of the double mode filter are cascade-connected.

[0049] This embodiment is characterized in that, by setting appropriate frequencies of the serial resonator, the attenuation amount at a high frequency side in the vicinity of a passband can be largely taken.

[0050] Fig. 11 shows an eighth embodiment of the present invention, and shows a configuration of the elec-

trode finger of the IDT formed on the piezoelectric substrate in the same manner as in the preceding examples. The embodiment of Fig. 11 is an extension of the embodiment of Fig. 10. and is configured so that the serial resonators configured having an IDT 120 and reflecting IDTs 121. 122 are further parallel-connected. with respect to the serial resonator configured having the IDT 110 and the reflecting IDTs 111. 112 which are cascade-connected to a so-called ladder type filter at the input side of the double mode filter.

[0051] In this configuration. the attenuation amount in the vicinity of the band can be largely taken without much deteriorating an insertion loss in a passing band. and a balanced filter can be realized.

[0052] Fig. 12 shows a ninth embodiment of the present invention and shows a configuration of the electrode finger of the IDT formed on the piezoelectric substrate in the same manner as in the preceding examples. The double mode filter is cascade-connected. The double mode filter at a first stage is configured by an IDT 113 connected to an input terminal IN. output IDTs 211. 212. and reflecting IDTs 311. 312.

[0053] The output IDTs 211. 212 of the double mode filter at a first stage are connected to the input IDTs 101. 102 of the double mode filter at a second stage. This embodiment is configured so that the output IDT 200 of the filter at a second stage is divided into the IDTs 201. 202.

[0054] In this embodiment. the insertion loss of the passband is small. and it is possible to realize the balanced filter having a high attenuation characteristic.

[0055] In the respective embodiments. the electrode fingers configuring the IDTs are formed and disposed on the piezoelectric substrate. As a piezoelectric substrate in which a loss of the surface acoustic waves which can propagate is minimized. and which has a wide band width. the present inventors have proposed previously the piezoelectric substrate in Japanese Patent Application Laid-open No. 8-179551. Accordingly. it is desirable that this piezoelectric substrate proposed previously is also used in the present invention.

[0056] This preferable piezoelectric substrate is a 40° to 44° rotated Y-X $LiTaO_3$ substrate (crystal). which is cut out from $LitaO_3$ single crystal rotated around the X axis at a rotated angle from the Y axis to the Z axis. the rotated angle being in a range between 40° and 44°. A 66° to 74° rotated Y-X $LiNbO_3$ substrate is also preferable. which is cut out from $LiNbO_3$ single crystal rotated around the X axis at a rotated angle from the Y axis to the Z axis. the rotated angle being in a range between 66° and 74°.

[0057] Furthermore. in the above description the SAW device used in the respective embodiments is unbalanced at the input side and balanced at the output side, but this is reversible. and it is also possible that the input side of the surface acoustic wave device according to the present invention is balanced. and the output side thereof is unbalanced for adaptation.

[0058] As the embodiments were described above with reference to the drawings. according to the present invention. it is possible to realize the surface acoustic wave device having an unbalanced-balanced transformation function. and an impedance transformation function between the unbalanced-balanced terminals.

[0059] Thus. it is possible to provide a small-sized configuration of the communication device. etc. on which the surface acoustic wave device is mounted.

Claims

1. A surface acoustic wave device. comprising an input interdigital transducer and an output interdigital transducer. disposed on a surface acoustic wave propagation path of a piezoelectric substrate. wherein

   when an aperture length of an electrode finger of the input or output interdigital transducer is denoted by X. the output or input interdigital transducer has two divided interdigital transducers each having an electrode finger in which each aperture length is denoted by substantially X/2. and wherein
   the two divided interdigital transducers are serially-connected. and the electrodes of the respective electrode fingers are led from the two divided interdigital transducers, and are disposed so that two output or input signals connected to a balance terminal pair have a different phase at 180°.

2. A surface acoustic wave device. comprising a plurality of interdigital transducers disposed on a surface acoustic wave propagation path of a piezoelectric substrate. and a reflection electrode disposed at both sides,

   wherein the plurality of interdigital transducers contain a first type of interdigital transducer and a second type of interdigital transducer disposed alternately. wherein

   when an aperture length of an electrode finger of the first type of interdigital transducer is denoted by X. each of the second type of interdigital transducers has two divided interdigital transducers each having an electrode finger in which each aperture length is denoted by substantially X/2. and wherein
   the first type of interdigital transducer is connected to an unbalanced input or output terminal pair. and the two divided interdigital transducers are serially-connected. and the electrodes of the respective electrode fingers are led from the two divided interdigital transducers, and are connected to a balanced terminal

pair. and the respective electrode fingers of the two divided interdigital transducers are disposed so that phases of signals in the balanced terminal pairs are different at 180°.

3. The surface acoustic wave device according to claim 1 or 2. wherein

in the two divided interdigital transducers. a position of the electrode finger at a side connecting with the balanced terminal is mutually slid in half-waves.

4. The surface acoustic wave device according to claim 2. wherein

the plurality of interdigital transducers constitutes a double mode filter by three interdigital transducers.

5. The surface acoustic wave device according to claim 2. wherein

the plurality of interdigital transducers are five or more interdigital transducers. constituting a multi-electrode filter.

6. A surface acoustic wave device comprising:

two or more filters being cascade-connected. of which an outermost filter includes
an input interdigital transducer and an output interdigital transducer. disposed on a surface acoustic wave propagation path of a piezoelectric substrate. wherein
when an aperture length of an electrode finger of the input or output interdigital transducer is denoted by X. the output or input interdigital transducer has two divided interdigital transducers each having the electrode finger in which each aperture length is denoted by substantially X/2. and wherein
the two divided interdigital transducers are serially-connected. and the electrodes of the respective electrode fingers are led from the two divided interdigital transducers. and are disposed so that two output or input signals connected to a balance terminal pair have a different phase at 180°. and
a balanced terminal pair being used as an input or an output.

7. A surface acoustic wave device comprising:

two or more filters being cascade-connected. of which the outermost filter including.
a plurality of interdigital transducers disposed on a surface acoustic wave propagation path of a piezoelectric substrate and a reflection electrode disposed at both the sides wherein
the plurality of interdigital transducers contain a first type of interdigital transducer and a second type of interdigital transducer disposed alternately. wherein
when an aperture length of an electrode finger of the first type of interdigital transducer is denoted by X. each of the second type of interdigital transducers has two divided interdigital transducers each having an electrode finger in which each aperture length is denoted by substantially X/2. and wherein
the first type of interdigital transducer is connected to an unbalanced input or output terminal pair. and the two divided interdigital transducers are serially-connected. and the electrodes of the respective electrode fingers are led from the two divided interdigital transducers. and are connected to a balanced terminal pair. and the respective electrode fingers of the two divided interdigital transducers are disposed so that phases of signals in the balanced terminal pairs are different at 180°: and
a balanced terminal pair being used as an input or an output.

8. The surface acoustic wave device according to any one of claims 1 to 7. wherein

the piezoelectric substrate is a 40° to 44° rotated Y-X $LiTaO_3$.

9. The surface acoustic wave device according to any one of claims 1 to 7, wherein

the piezoelectric substrate is a 66° to 74° rotated Y-X $LiNbO_3$.

10. A surface acoustic wave device comprising an input interdigital transducer and an output interdigital transducer each constituted by interdigitated electrode fingers and disposed side-by-side on a surface acoustic wave propagation path of a piezoelectric substrate, wherein:

one of the interdigital transducers comprises first and second electrode fingers interdigitated to form a pair and extending transverse to said propagation path along an aperture length;
the other interdigital transducer comprises third and fourth electrode fingers each extending transverse to said propagation path along respective halves of said aperture length. the third and fourth electrode fingers being mutually offset along said propagation direction by half the wavelength of said surface acoustic wave; and

terminals connected to said third and fourth electrode fingers so as to define a balanced pair of input or output terminals in which respective signals have a 180° phase difference.

FIG. 1

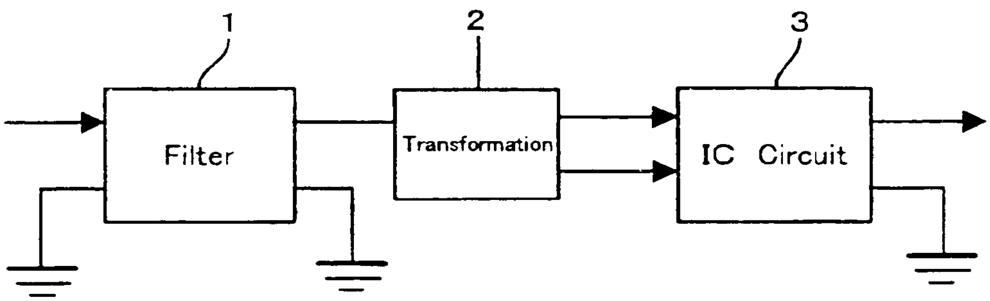

1
2
3
Filter
Transformation
IC Circuit

FIG. 2

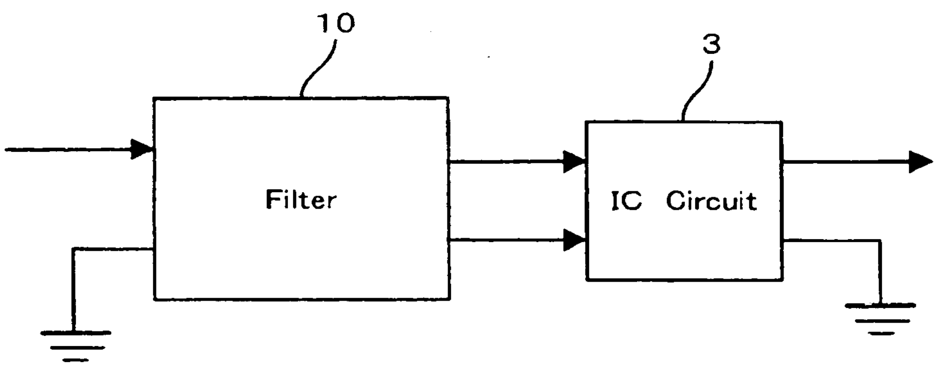
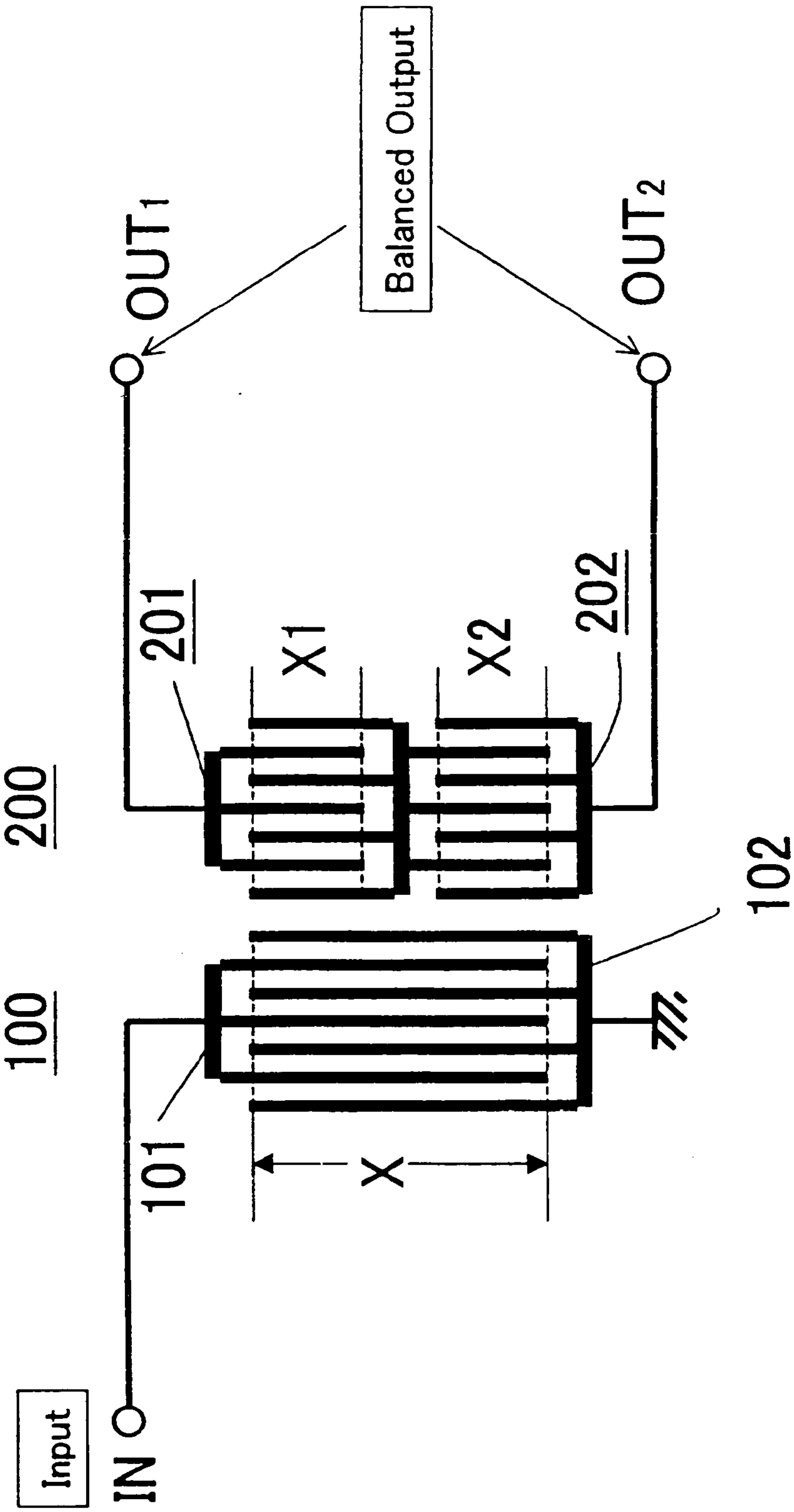

10
3
Filter
IC Circuit

FIG. 3



Input
IN
100
101
102
X
200
201
202
X1
X2
OUT1
OUT2
Balanced Output

FIG. 4

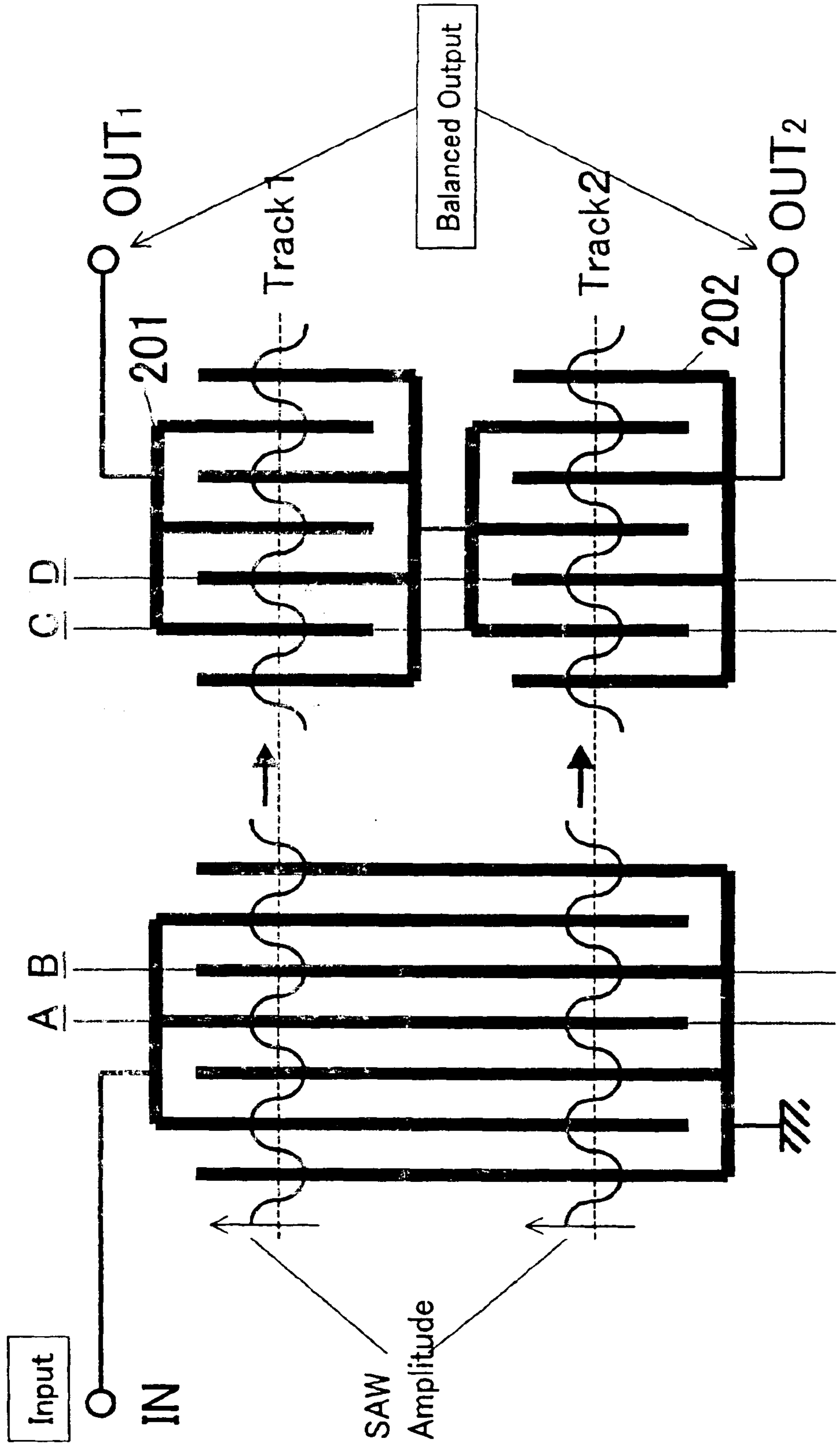

Input
IN
SAW
Amplitude
100
A
B
200
C
D
201
202
Track1
Track2
OUT1
OUT2
Balanced Output

FIG. 5

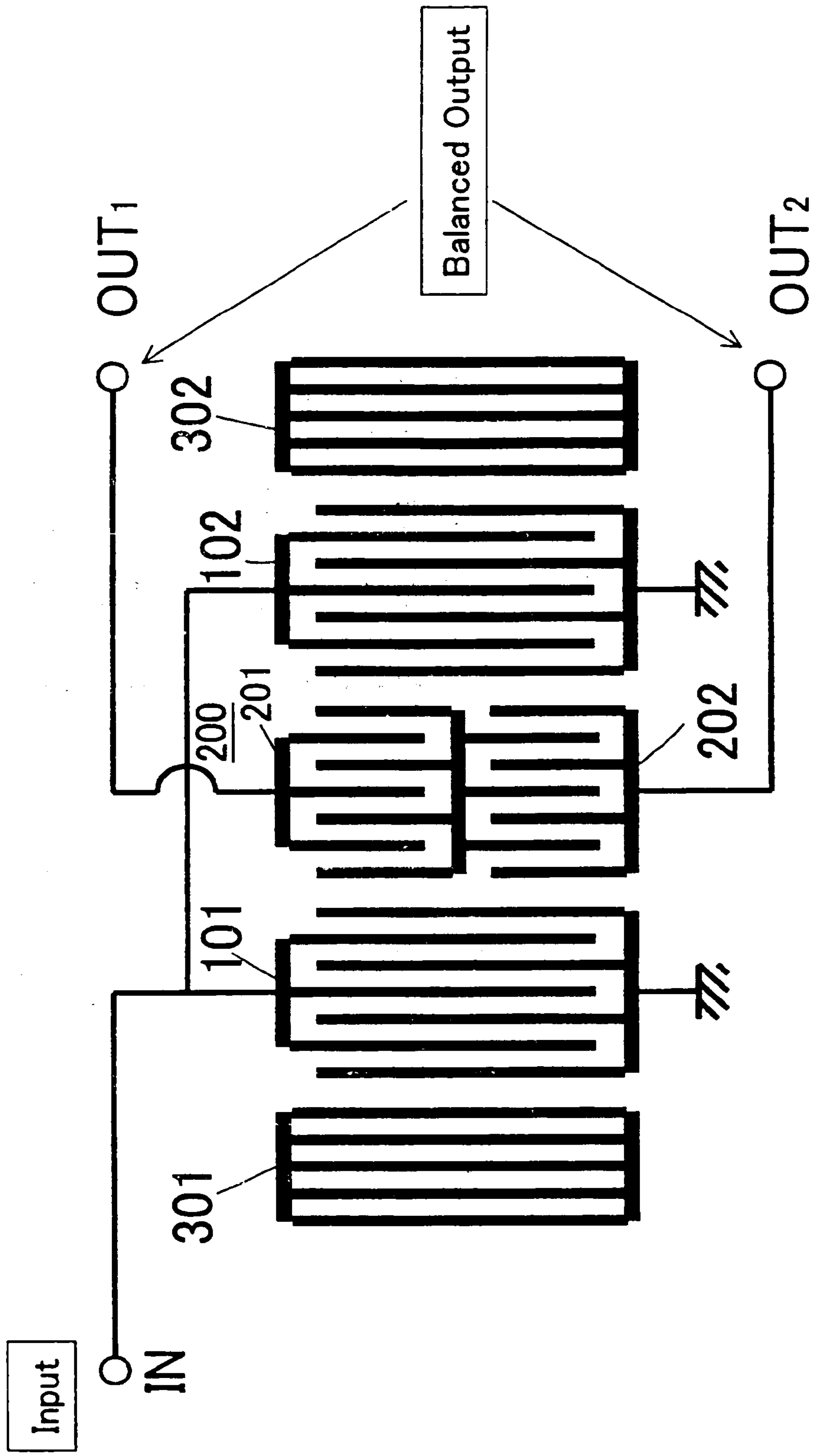

Balanced Output
OUT1
OUT2
302
102
200
201
202
101
301
IN
Input

FIG. 6

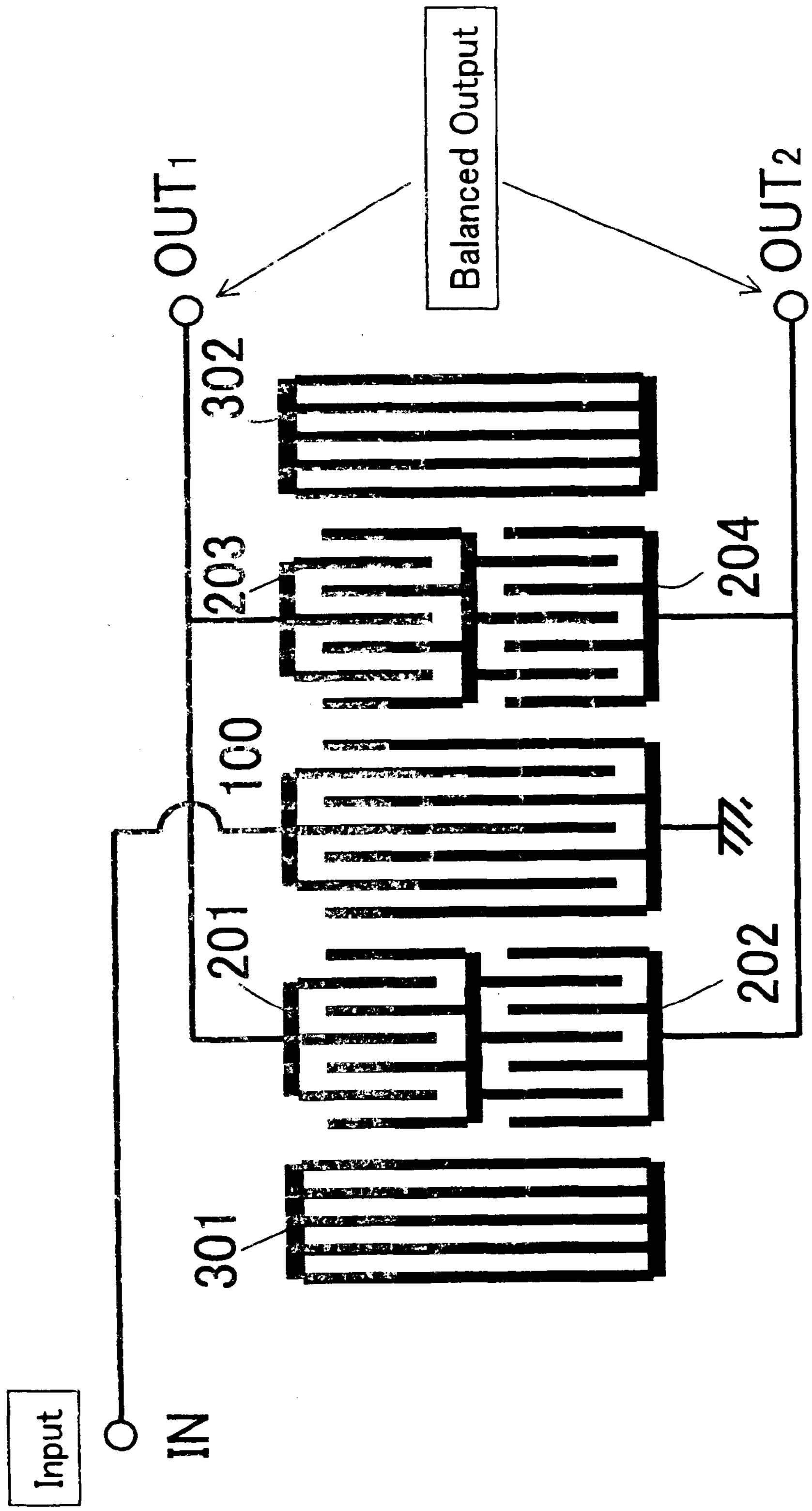

Input
IN
OUT_1
OUT_2
Balanced Output
301
201
202
100
203
204
302

FIG. 7

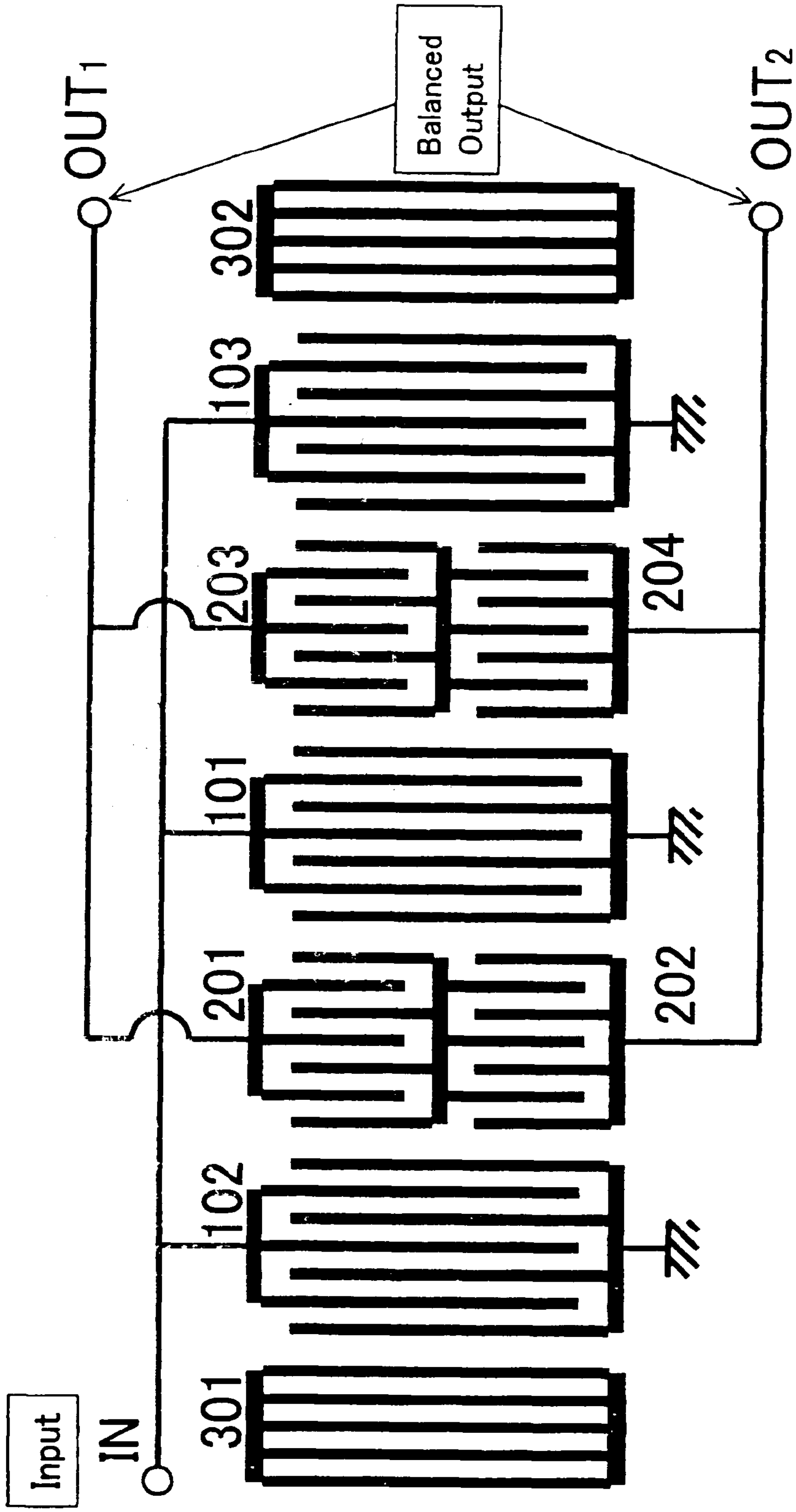

Balanced Output
OUT1
OUT2
302
103
203
204
101
201
202
102
301
IN
Input

FIG. 8

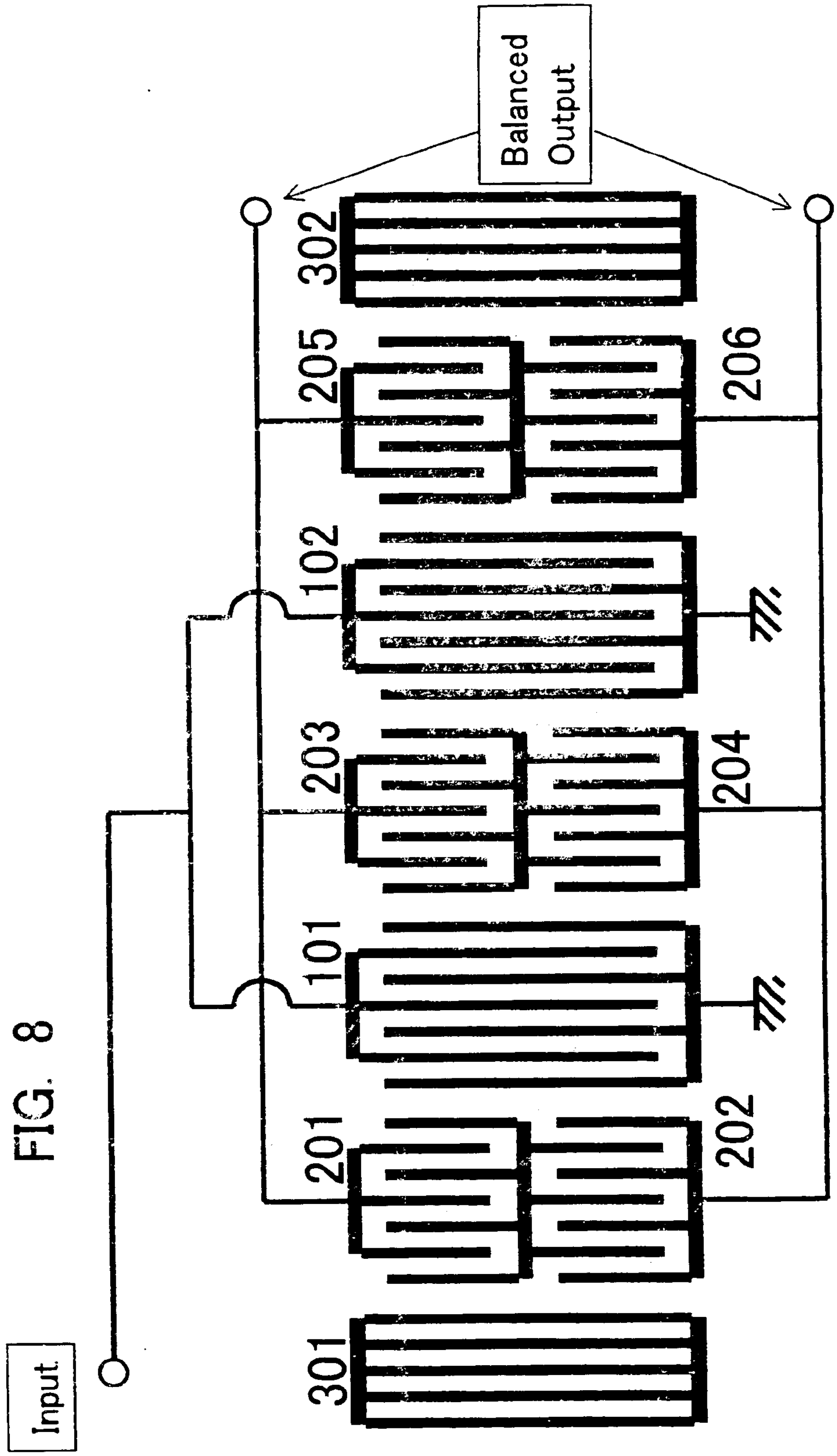


FIG. 9

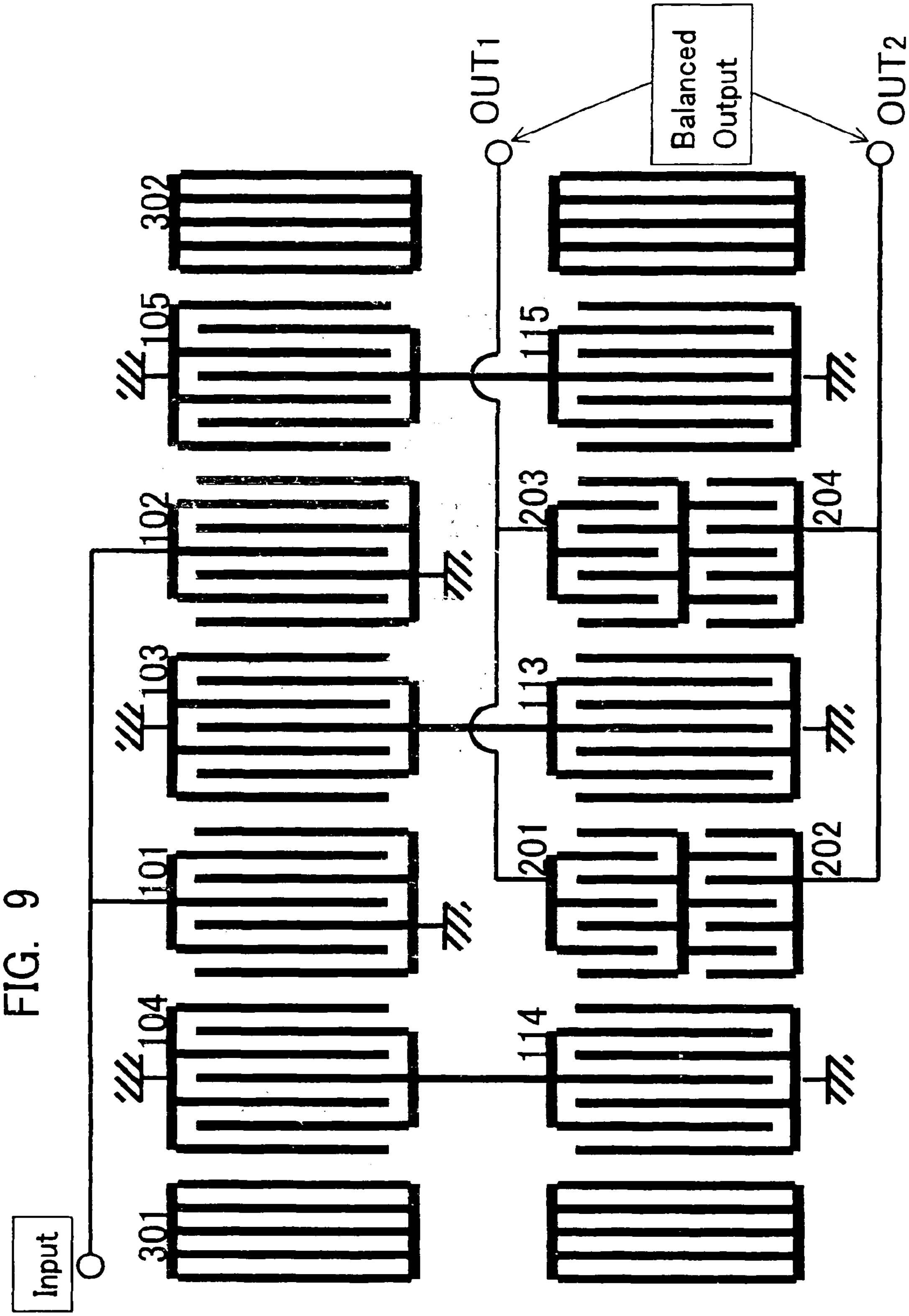

Input
301
104
101
103
102
105
302
114
201
202
113
203
204
115
OUT1
OUT2
Balanced Output

FIG. 10

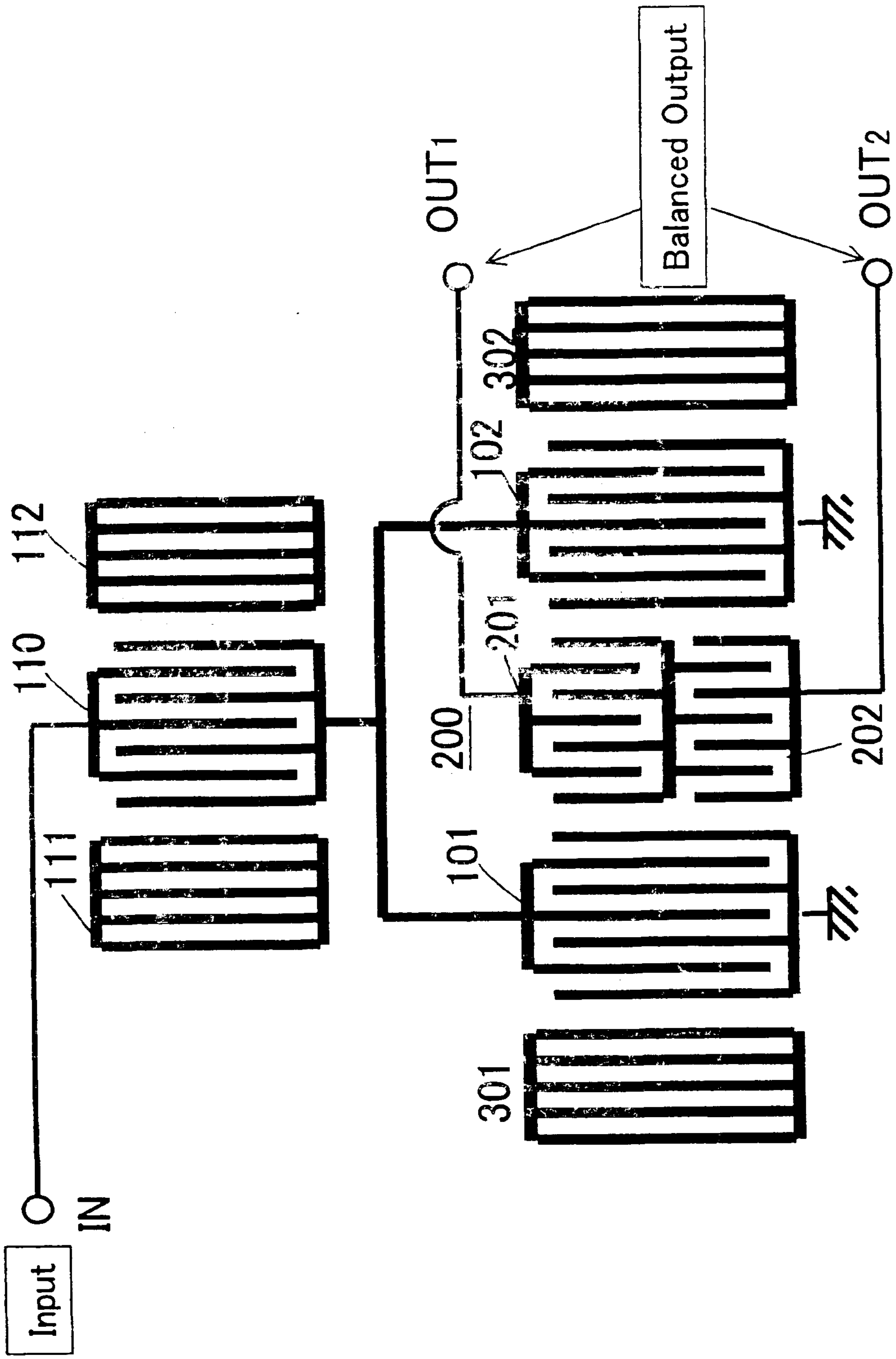

Input
IN
111
110
112
301
101
200
201
202
102
302
OUT1
OUT2
Balanced Output

FIG. 11

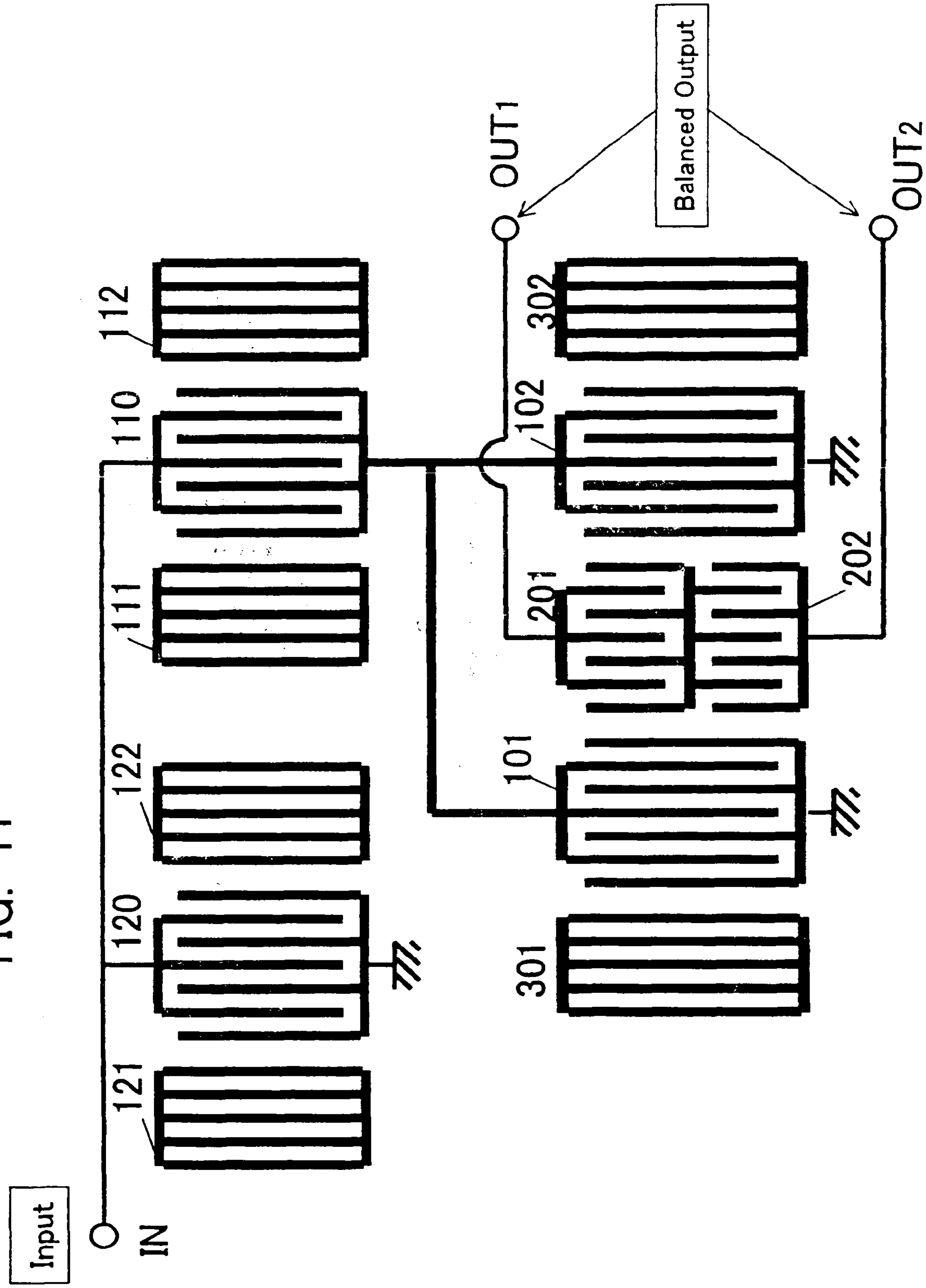
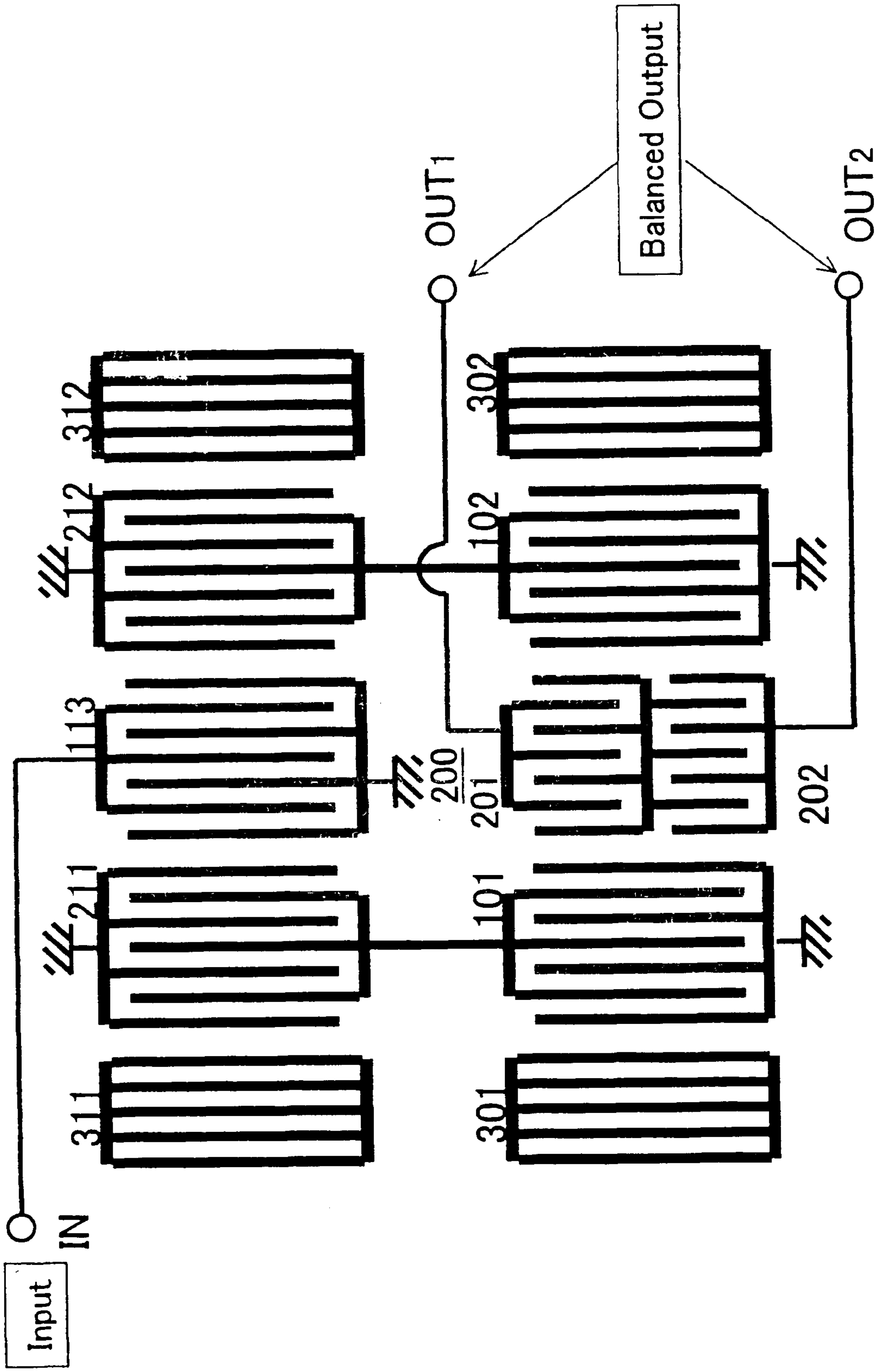

Input
IN
121
120
122
111
110
112
101
201
202
102
302
301
OUT1
OUT2
Balanced Output

FIG. 12


Input
IN
311
211
113
212
312
301
101
200
201
202
102
302
OUT1
OUT2
Balanced Output